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MEMORANDUM REPORT NO. 1244
January 1960

THE EFFECTIVENESS OF BASE-BLEED IN REDUCING DRAG OF BOAT-TAILED BODIES AT SUPERSONIC VELOCITIES

Elizabeth R. Dickinson

Department of the Army Project No. 5B03-03-001
Ordnance Management Structure Code - 5010.11.814

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

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A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

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ABSTRACT

The effectiveness of reducing the drag of a square-based projectile by bleeding air into a hollow in the base has been established by means of wind tunnel tests. This report describes both a brief free-flight experimental test and some theoretical calculations made to determine the effect of base-bleed on a boat-tailed projectile. There was no decrease in drag.

Wind Tunnel Tests at the NACA Lewis Laboratory showed that the drag of a square-based projectile could be appreciably reduced by bleeding air into a hollow in the base of the projectile.[1] An optimum bleed area, for minimum drag, was determined. Free flight tests at the Ballistic Research Laboratories showed that the drag of a square-based projectile could be appreciably reduced by means of boat-tailing the base of the projectile. An optimum angle and length of minimum drag were established.[2] It was therefore hoped that the effects of base-bleed and boat-tailing might be cumulative.

Both a brief experimental test and some theoretical calculations were made, to determine the effect of base-bleed on a boat-tailed projectile.

Twenty-millimeter models of a fairly conventional shell configuration were used as the test vehicles (Fig. 1). Several boattail modifications were designed, varying the number and size of the bleed holes. In all cases, however, the optimum bleed criteria of reference 1 were adhered to as closely as practicable. First, the ratio of the open area in the base to the body cross-sectional area (A_b/A_m) was maintained at 0.25; second, the ratio of the side-rear intake area to the body cross-sectional area (A_s/A_m) was maintained at 0.35. In addition to the base-bleed models, there were three other types designed as controls: a model with solid boattail, one with the cavity but no holes, and one with the cavity and partial holes which did not go through into the cavity (Table I).

It is realized that there are differences in flow characteristics over a square base as compared with a boat-tailed base. These differences would lead one to believe that optimum bleed parameters for a square base would not be those for a boattail. As some values for these parameters had to be adopted, and as all values had shown an effect in the NACA tests, the optimum bleed criteria of reference 1 seemed to be a reasonable starting point. If any effects were noted, an attempt would then be made to determine optimum bleed criteria for boat-tailed bases.

All of these types were fired, at approximately M = 1.45, in the Aerodynamics Range of BRL.[3] The data were reduced in the usual way, and corrected to zero yaw.[4] The results were completely negative: none of the drag coefficients differed, within the experimental accuracy of the data (1%), from that of the solid boat-tailed model. Similar results were obtained from firings of 105-mm base-bleed shell.[5] It should be noted, however, that in the case of the 105-mm shell, the (A_s/A_m) ratio was considerably less than 0.35.

Not only were models fired through the ranges, but flow calculations were made, by the method of characteristics, to obtain the pressure distribution over the body at M = 1.45. In addition, base pressure was calculated by a method similar to that of reference 6. As can be seen in figure 2, the pressure difference between the boattail surface and the base is very small. What little bleed might be expected due to this pressure difference is decreased by an effective decrease in hole size due to turbulence, and also by internal friction.

Base-bleed does not appear to be the optimum means of reducing the drag of a projectile at supersonic speeds. Although optimum base-bleed design results in a 7% drag decrease for a square-based body, an optimum boattail (either added to the body, or formed from a constant overall length) results in an 18% drag decrease.

Elizabeth R. Dickinson

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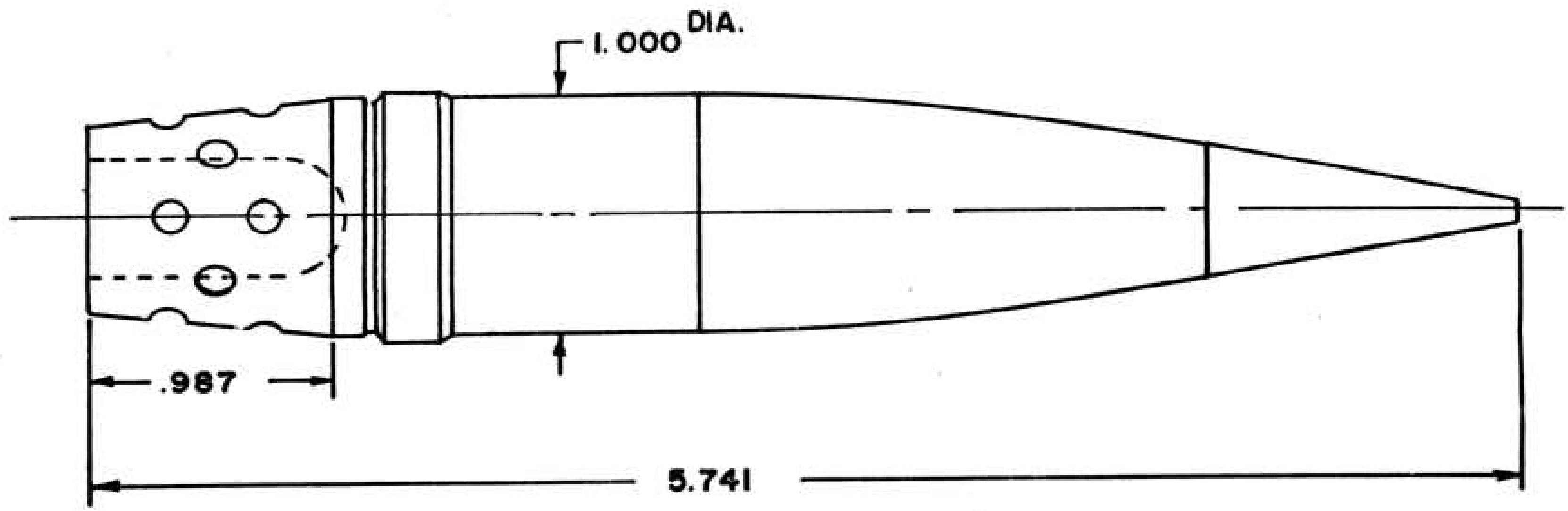
TABLE I

Projectile Types

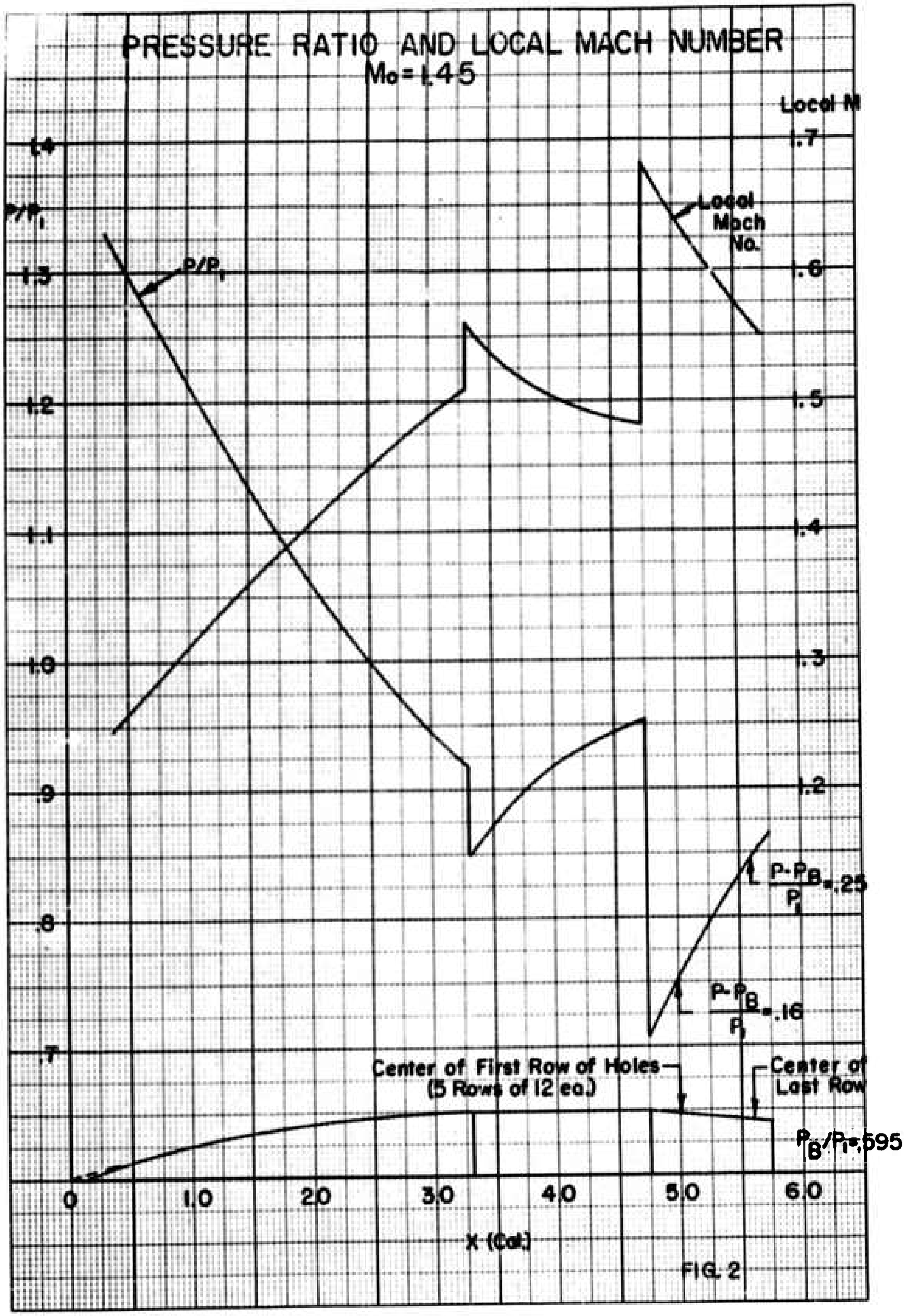
Type	Number of Holes	Arrangement of Holes	Remarks
1	0		Solid boattail
2	0		Hollow boattail
3	15 (partial)	3 rows of 5	Holes did not go through into cavity
4A	60	12 rows of 5	
4B	30	5 rows of 6	
4C	15	3 rows of 5	
4D	15	3 rows of 5	Holes slanted forward at angle of 45° with axis
5A	4	1 row of 4	Axial slots
5B	4	2 rows of 2	Transverse slots

BASE BLEED PROJECTILE



NOTE: ALL DIMENSIONS ARE IN CALIBERS

FIG. 1



PRESSURE RATIO AND LOCAL MACH NUMBER
Mo=1.45
Local M
P/P1
Local Mach No.
P-PB / P1 =.25
P-PB / P1 =.16
Center of First Row of Holes (5 Rows of 12 ea.)
Center of Last Row
PB/P1=.595
X (Cal.)
FIG. 2